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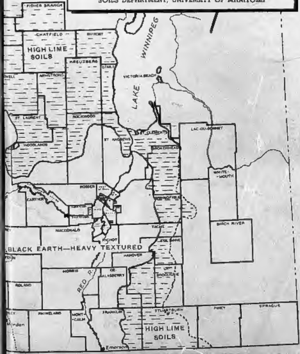
The Land for Thine Inheritance

by

J. H. ELLIS

SOILS DEPARTMENT, UNIVERSITY OF MANITOBA



FOREWORD

This is one of a series of booklets prepared for the use of study groups formed for the purpose of discussing problems of interest to the rural people of Manitoba. The series has been prepared under the direction of a committee appointed by the Minister of Agriculture for Manitoba and includes booklets with the following titles: Why Organize? Co-operation, Credit Unions, Wheat Studies, Homemaking, Foods and Health, Public Speaking, Soil Conservation, Livestock Marketing, Poultry Marketing, Rural Community Health. Some of the books are issued in French as well as in English. This material is designed for the use of small groups, preferably from five to ten persons, meeting regularly for the systematic study of the subject chosen. Copies will be supplied free to all members of such groups.

For the use of group leaders two booklets are available: (1) A Guide for Discussion Leaders and (2) Recreation.

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THE LAND FOR THINE INHERITANCE

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SECTION I

SOILS AND LAND USE IN MANITOBA

In Manitoba it has become commonplace to think of soils (both zonal soils and local soils) as excellent, good, fair, poor or sub-marginal according to their suitability for agricultural use. Be that as it may, from an agricultural standpoint or from the relative ease with which the soils may be exploited, the fact remains that all soils are capable of producing something. In considering soils as a natural resource, therefore, we should think of the specific use or uses for which the soils are best adapted. One soil may be good for the production of grain but poor for the production of hay; another soil may be sub-marginal for the production of wheat, but excellent for the production of grass; another soil may be poor for arable culture but a valuable asset if used as range land; while still other soils may be more suited to the production of pulp wood, game, fur and wild life, or for recreational use. If we think of soils in this light, the soil resources of Manitoba are a rich legacy bequeathed to the citizens of the province to use, to enjoy, and to pass on unimpaired to future generations.

This rich legacy of Manitoba soils may be considered as a vast estate of 161,172,480 acres, of which 143,857,280 acres are land and 17,315,200 are water. Only a part of this vast estate is privately owned. This is shown by the fact that approximately 21,-388,800 acres are alienated from the Crown and the remainder is Crown land. Approximately 15,202,080 acres of the land alienated from the Crown is held as farms. Of the land which is held as farms, 52.6 per cent. is under cultivation and 47.4 per cent. is uncultivated. These figures may be visualized better if we try to picture a township of 36 sections, and assume that this township represents the province. In this case four and three-quarter sections would represent the land alienated from the Crown, and thirty-one and one-quarter sections would be public property. Of the four and three-quarter sections alienated, the land farmed would be three and two-fifths sections, and of the three and two-fifths sections of farm land, only one and three-quarter sections would be cultivated.

It is also of interest to note that whereas three and two-fifth sections in the township would represent the amount of land which is farmed, the area in lakes would be equal to three and four-fifth sections. In other words, the water area is about twice as large as the area under cultivation.

In considering the use of land in Manitoba, the subject divides itself naturally into two main divisions: (1) the use that is made of the farm lands, and (2) the use that is made of the land not held as farms.

(1) **The use made of farm lands:**

It is significant that the farms are situated in the southern and south-western portion of the province, chiefly on the black-earth soils, the northern black-earth soils, the dark brown-black-earth transition soils and black-earth soils that have undergone woodland invasion. These coincide with the prairie and aspen grove areas.

For purposes of collecting agricultural statistics the organized portion of the province is divided into 14 crop reporting districts.*

Figure 1

The location of each of these districts is shown in Figure No. 1. The total acreage of farm land in each crop reporting district and the amount of land which is cultivated and not cultivated is shown in Table No. 1. The figures here used have been calculated as a recent five-year average in order to smooth out slight annual fluctuations.

*See Provincial Crop Reporting Bulletins (Annual).

TABLE No. 1 CONDITION OF ALIENATED LAND IN MANITOBA

Acreage of Land in Crop Reporting Districts, and Amount of Land in Farms, Cultivated and not Cultivated

CROP REPORTING DISTRICTS	(1) Estimated Area in Crop Districts	(2) Acreage Listed as Farm Land	(3) Percent of Land in Farms	(4) No. of Farms	(5) LAND LISTED AS FARMS 5-YEAR AVERAGE (1934-38)		PER CENT. OF FARM LAND	
					Acres Cultivated	Acres Not Cultivated	Cultivated	Not Cultivated
1. Melita	1,098,200	895,660	81.5%	1,900	509,068	386,592	56.8	43.2
2. Killarney	1,923,121	1,830,796	95.2%	4,580	1,202,826	627,970	65.7	34.3
3. Red River	3,649,944	3,121,867	85.5%	10,940	2,083,918	1,037,949	66.7	33.3
4. Winnipeg	194,945	162,817	83.6%	1,240	119,396	43,421	73.3	26.7
5. Springfield	955,153	632,374	66.2%	4,370	330,432	301,942	52.2	47.8
6. Eastern	2,972,608	573,879	19.3%	3,670	132,818	441,061	23.1	76.9
7. Virden	2,125,775	1,868,697	87.9%	4,840	1,044,070	824,627	55.9	44.1
8. Carberry	1,440,960	1,200,835	83.1%	3,260	777,030	423,805	64.7	35.3
9. Neepawa	1,135,373	822,450	72.4%	2,740	474,130	348,320	57.6	42.4
10. Russell	2,013,441	1,629,788	80.9%	5,240	559,828	1,069,960	34.3	65.7
11. Dauphin	1,304,960	895,392	68.6%	3,640	386,406	508,986	43.1	56.9
12. Mid-Lake	3,927,855	757,439	19.3%	4,640	132,000	625,439	17.4	82.6
13. Swan River	989,760	428,973	43.3%	2,000	150,512	278,461	35.1	64.9
14. West Shore	2,701,878	381,119	14.1%	2,140	89,960	291,159	23.6	76.4
TOTALS	26,433,973	15,202,086	57.5%	54,700 +3,074 67,774	7,992,394	7,209,692	52.6	47.4

(1) Total area calculated from Provincial Map of Crop Reporting Districts.
(2) Total land in farms calculated from 1936 Dominion Census data.
(3) Per cent. of land in each district listed as farm land.
(4) Figures taken from Crop Reporting Bulletin 116 (1937) which gives number of farmers in Crop Reporting District operating significantly. This leaves a balance of 3,074 individuals classed as farmers whose farming operations are considered relatively insignificant.
(5) Manitoba Crop Reporting Bulletins.

TABLE No. 2

Percentage of Cultivated Land Occupied by the Various Classes of Crops in Manitoba (1934-1938)

Figures give the five-year average in per cent. of each group of crops, and indicate agricultural land-use of arable land by Crop Reporting Districts, as well as estimated annual production of wild hay in tons per 100 acres of cultivated land.

District No.	UTILIZATION IN PER CENT OF THE TOTAL CULTIVATED AREA					Native Hay in Tons
	Fallow	Intertilled Crops	Grasses & Legumes	Cereal Crops	TOTAL	Per 100 ac. Cult Land
1	20.9	1.4	2.7	75.0	100	6.2
2	21.72	0.62	3.31	74.35	100	5.8
3	18.7	1.8	7.1	72.4	100	6.1
4	12.92	4.44	11.33	71.31	100	4.2
5	15.3	3.1	13.0	68.6	100	16.5
6	9.3	2.7	30.1	57.9	100	18.6
7	27.2	.9	3.7	68.2	100	7.2
8	24.5	1.1	5.4	69.0	100	4.6
9	25.38	.66	7.68	66.28	100	8.6
10	27.21	.51	2.14	70.14	100	12.5
11	26.6	.6	9.1	63.7	100	10.4
12	17.0	2.6	13.6	66.8	100	115.3
13	16.3	.9	10.4	72.4	100	8.8
14	23.78	1.31	6.06	68.85	100	74.7
Prov. Mean	21.95	1.29	6.28	70.48	100	

The use which is made of the cultivated land in each of the respective crop reporting districts is shown also as a recent five-year average in Table No. 2. The figures in this table show the average of the various classes of crops per 100 acres of cultivated land.

The figures in Table No. 2 indicate some variation in the use made of the cultivated land in the different districts, just as within each district differences in land use will occur from farm to farm, but taking the province as a whole, these figures show that on the cultivated farm lands, cereal crops on an average constitute 70.48 per cent., fallow 21.95 per cent., grasses and legumes 6.28 per cent., and intertilled crops 1.29 per cent. Thus, out of every 100 acres of land under cultivation, from 92 to 93 acres are used for the growing of grain crops or for fallow preparatory for grain crops. If cereal crops are classed as soil exhaustive crops and the grasses and legumes as soil improvement crops, the effect of this fallow-grain system of land use on soil productivity is thought-provoking.

In connection with land use it is also of importance to note the numbers of livestock (kept in the respective crop reporting districts) that require summer pasture and winter feed. The animals which consume forage crops are horses, cattle and sheep. For purposes of comparison these three classes of stock are calculated as animal units.*

The average number of animal units per 100 acres of cultivated land in the respective crop reporting districts is shown in Table No. 3.

TABLE No. 3

Units of Livestock per 100 acres of Cultivated Land in Manitoba (5-year Average 1934-1938)

DISTRICT NO.	Units of Horses Per 100 Acres	Units of Cattle Per 100 Acres	Units of Sheep Per 100 Acres	Total Units Per 100 Acres
1	2.86	4.77	16	7 78
2	3.07	5.04	.206	8.31
3	2.32	5.22	256	7 79
4	3.45	9.12	16	12.73
5	4.32	11.28	.30	15.89
6	6.19	21.88	1.69	29.75
7	3.55	6.92	19	10.65
8	3.22	6.10	.33	9.66
9	3.83	8.54	.52	12.89
10	4.89	10.23	.20	15.32
11	4.30	10.43	.50	15.24
12	10.31	45.21	2.76	58.28
13	5.68	11.69	.42	17 79
14	6.74	24.42	1 11	32.28

A comparison of the number of units of livestock with the number of acres seeded to grasses and legumes, and the number of tons of native hay cut on an average in the respective crop reporting districts, brings out a fact of striking importance. This fact is that if all the cultivated grasses and legumes in the province were cut for hay, and added to the tonnage of native hay, the tonnage would not be sufficient to provide for the winter feeding of the animals kept. On many farms dependence for winter roughage is placed on oat sheaves or on straw. Consequently, if the cereal crops fail, there is a general shortage of fodder. In a number of crop reporting districts, fodder corn is a valuable and important source of roughage, but the amount of corn is relatively small in proportion to the total number of livestock in the respective districts. No information is available on the amount of pasture provided for the stock in Manitoba during the summer months, but

*One animal unit—one mature horse, or one cattle beast over two years old, or six mature sheep.

as approximately 47.4 per cent. of the farm land is not under cultivation it must be assumed that the stock are pastured largely on native or unbroken pasture, except when they are running on the stubble and summerfallow.

From a land use standpoint the fact should be stressed, that the livestock which are already being kept on the farms in Manitoba can utilize a larger acreage of grasses and clovers. From a soil improvement standpoint, as well as from a livestock standpoint, an increase in the acreage of grasses and legumes on many farms is urgently needed.

The figures which have been given to show the use of cultivated land in Manitoba indicate that in the prairie sections of the province the type of farming which is now followed on the cultivated lands is chiefly grain growing. A limited portion of the arable land is contributing to the support of the livestock which are generally kept as a supplementary enterprise. Consequently the stock must depend in a large measure on the uncultivated land for support. The problem which has to be solved is, can the soils of Manitoba be kept productive under the present system of land use?

The general utilization of the arable land in Manitoba for grain growing is the result of two factors: (1) the suitability of the land for the production of grain, and (2) the ability (in the

PROVINCE OF MANITOBA
COMPARISON OF CLASSES OF FARM CROPS

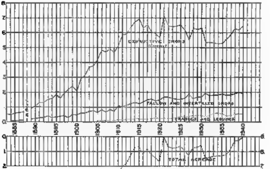


FIGURE No. 2

past) to dispose of the grain as a marketable commodity. These two factors have influenced the agricultural pattern and the way of life on the land.

The crop acreage figures for the last 50 years indicate that the type of land use on the farms in Manitoba has changed but little since the early days of settlement (except in a few local areas). (See Figure No. 2.) While this figure does not indicate much change in the type of arable land use, it does bring out very strikingly that two distinct periods of agricultural development have occurred.

The first period in agricultural development came to a close about 1915. This period from the early 80's to 1915 was one of rapid expansion of acreage. During this period the better lands on the prairies and in the aspen grove area were brought under cultivation. Expansion of settlement into the forested area took place only to a slight degree.

The second agricultural period commenced about 1915 and continued to the present time. During this period the total acreage under cultivation has not increased to any appreciable extent. Any additional acreage of virgin land that was brought under cultivation has been off-set, and in some years more than off-set, by the land which has been abandoned or let go out of cultivation.

In connection with the agricultural land use in Manitoba, therefore, two points must be stressed.

The first point is that the cultivated acreage in Manitoba appears to have reached an equilibrium with the area of soils that are most suitable for the type of agriculture which is being practised. The expansion of agricultural acreage continued in Western Canada long after it had slowed down in Manitoba. Had the prairie and prairie soils extended over a larger acreage in Manitoba, the cultivated acreage also would have expanded. Hence we should recognize that the reason agriculture has not expanded east and north of Lake Winnipeg, and in the Inter-Lake area, is because these areas do not lend themselves to the present general system of agriculture followed in this province (grain growing). This does not mean that the soils of the province which have not been broken up are sub-marginal, because as it has been pointed out, all soils are capable of producing something; but it does mean that the forest soils, unlike the prairie soils, do not lend themselves to easy exploitation, and that the soils of these lands do not attract the settler who plans to engage in grain production.

The second point is that if agricultural expansion into new areas awaits the creation of markets for the type of produce

which can be produced on the forest soils, then individually and collectively we in Manitoba should be vitally concerned with the preservation of the lands which are now under the plow. Each year since 1915 the provincial crop reporting bulletins list so many thousand acres of new breaking, and yet the total cultivated acreage has not increased. What is the answer?

The time has come when a man should no longer be permitted to ruin a farm by exploitation and then to seek a new area in which he may repeat the process. Individually, the farmer, for his own as well as for his children's sake, must conserve the productivity of his farm. Collectively, both taxpayers and administrators (municipal and provincial) must be concerned with soil productivity and permanent agriculture because the land is the tax base. The land (the tax base) must be protected if a municipality or a province is to survive as a self-governing unit.

(2) Use made of land not held as farms:

The lands which are not held as farm lands include both productive and non-productive forest, brush, swamp and muskeg, wet grasslands, rock, roads and towns. Some of the virgin lands are under timber and pulp leases, some are held as forest reserves, and others as vacant Crown lands. These non-farm lands are a source of revenue to the province and produce forest products, furs, game, and recreational facilities, moreover the lakes produce fish. All these should be used, but they should also be developed and conserved, not exploited. When the time comes so that markets are available for the type of farm products that can be grown on the better soils of the present non-farmed area, then further agricultural expansion will be justified. Otherwise land settlement in such areas can be of the subsistence type only.

Questions:

1. Why is such a relatively small portion of the soils of Manitoba used as farm land?
2. What use is made of the land on the farms in Manitoba as a whole?
3. What use is made of the land on the farms in your district?
4. Calculate the winter feed and summer pasture required for the stock kept in your district, and ascertain if a balanced program of land use is being followed.
5. What use is made of the land not held as farms in Manitoba?

SECTION II

SOILS—WHERE AND WHAT THEY ARE

The formation of soils is a complex chemical and biological process that takes place only at the surface of the earth where there is air and where there is life. When we speak of soils we are referring to natural objects formed at, and only at the surface of the earth, where the minerals from the disintegrated rocks intermingle and combine with the vegetation under the influence of climate and of micro-organisms (bacteria, etc.). To understand soils it is necessary to recognize that they are not merely powdered rock. The powdered rock or mineral fragments provide the soil with a skeleton, but skeleton material alone cannot make a soil. A fertile black prairie soil may contain sand intermixed as skeleton material, but if the surface deposit were made up entirely of sand it would be merely a sand pile. Sand dunes are "skeleton soils." The material in a freshly excavated clay pit likewise would be of little immediate value for the growing of crops unless it were exposed to the weather (climate) and to the action of living organisms (bacteria and plants). With time, as the clay developed soil characteristics, it would become more fertile. Without organic matter and micro-organisms the clay would be of low fertility. On the other hand, plants alone cannot make soil. No amount of dry, unaltered plant tissue could by any stretch of the imagination be considered as soil, for it is only as the plant material is decomposed and broken down by micro-organisms (bacteria, etc.) that the plant food which is contained in the dead plants can be made available to other plants. Therefore (although soils may contain sand, clay and plant material), neither sand alone, nor clay alone, nor plant material alone can make a soil. Sand may make glass, clay may make bricks, and dry grass may make a haystack, but mix sand and clay and grass together, expose them to the weather and to the action of bacteria for a thousand years or so on the Portage plains, and the end result would be a fertile black prairie soil.

We can now state by definition what soil is. Soil is that layer of the earth's crust that lies within the reach of those forces which influence, control or develop organic life, and within the range of influence of life itself.

Here we should note an important fact in regard to agricultural husbandry. Not only do plants and micro-organisms play an important part in soil formation, but animals and man (by modifying vegetation, as well as by tillage), exert a profound effect upon the soil. Anything which can be built up can be pulled down. It has been shown that sand and clay with the addition of organic

matter and organisms can be built up by climate to make soil. It must be also recognized that this process can be reversed. If all the organic matter and the organisms were taken away from a soil, the remainder (i.e., the sand and clay) would be powdered minerals which would cease to be soil.

It is important therefore, to recognize that soils are subject to change, and that they can be affected by culture for better or for worse. Soils respond to and are determined by their environment. The virgin prairie soils were built up under grassland vegetation. Climate (i.e., temperature and moisture) determined the species of plants that would thrive. Climate determined the amount of growth and consequently the amount of vegetative material that would be produced each year. Soil-climate likewise controlled the activity of the soil micro-organisms (bacteria, etc.), and determined each season how much of the organic matter produced by the higher plants would be broken down and decomposed. If the season was moist the soil organisms were active, more organic matter was broken down and more plant food elaborated. Consequently, more grass grew to produce more organic matter. If, on the other hand, the season was too dry for grass to grow vigorously, the soil was also too dry for the soil organisms to act vigorously, so that when there was less growth there was also less destruction of organic matter. The production of organic matter by the higher plants and its destruction by the soil organisms throughout the ages thus kept the soil organic matter at a balance, and as long as nature was not disturbed by the activities of man, the organic matter in the soil was first built up and then maintained at a level that was in equilibrium (or in a state of balance) with the soil climate.

With the breaking of the prairie sod and the introduction of grain growing, a marked change was brought about as a result of "culture." Soil moisture and nutrients were taken up by grain crops instead of by grass. The grain was removed and the straw threshed into piles so that only stubble and roots remained. Hence, while the total amount of crop produced (plant material) was determined by climate and soil fertility, the amount which was added to the soil was determined by man. The amount of organic matter added to the soil under grain-farming, namely, roots and stubble, was very much less annually than the amount of organic matter added by grass under virgin prairie. As less organic matter was added, there was less energy material for the soil organisms to work on, and the natural balance between production and destruction was upset.

In the production of grain in the prairie region it was soon found that dependence could not be placed on precipitation to

provide enough water for a grain crop each year, and in order to store water in the soil, as well as to control weeds, the practice of summer-fallow had to be adopted. The moist condition of the soil during the warm part of the fallow year when the growth of vegetation was prevented by tillage, favoured the activity of the soil micro-organisms (bacteria, etc.), and consequently favoured the more rapid destruction of the soil organic matter. Under the fallow-grain system a new balance (equilibrium) of organic matter was inevitable, and now (on an average) the cultivated soils of the prairie have only about two-thirds as much organic matter as virgin soils. (In other words the organic dollar is now worth about 66 cents.)

If the lowering of the organic matter of the soil to a new level by the growing of grain were the only factor involved, the better prairie soils would still remain fertile for many years, because the leaching of plant nutrients is not an important factor in soil deterioration under the climate of the prairie region. However, a condition is brought about by fallow-grain culture which predisposes to serious soil deterioration unless steps are taken to prevent or control it. Under grain growing the surface of the soil is exposed, not only during the fallow year, but also during part of the crop year. This exposure of the bare soil predisposes to soil drifting and erosion. (This deterioration may result in the organic dollar being reduced to "ten cents" or may even make it look like "30 cents" with the 3 knocked off.) It is soil drifting and soil erosion, rather than the production of crops, that have been responsible for the serious deterioration of certain prairie soils.

It is apparent, therefore, that although climate, vegetation and mineral material are the chief factors involved in the formation of virgin soils, nevertheless arable soils can be profoundly affected for better or for worse by culture or the work of man. Consequently, it is highly important to remember that soils are not static or inert. They are vital living objects that progress from youth through maturity to old age. They can become sick and worn out, or they can be rejuvenated. Like any other living thing they will eract favourably to understanding and care, on the other hand, even though they are long-suffering, they will either rebel or perish if continually subjected to exploitation and abuse.

Questions:

1. Why are the soils developed under prairie grasses dark in color?
2. What would happen to the fertility of a field if all the dark colored surface soil were stripped off with road building machinery?

3. What are the natural conditions under which the surface soil may be removed as effectively as if it were taken off by machinery?
4. What is the effect on soil organic matter and on soil fertility if a farm is kept under a "fallow-grain growing" system indefinitely?

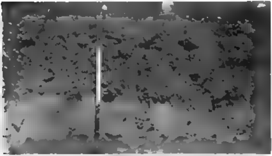


FIGURE No. 3

The good earth. A cross-section through a black-earth profile showing organic matter mixed in the soil to a depth of almost two feet. Moreover the clay loam texture of the subsoil indicates good water retention capacity. With care such soils can be kept permanently productive.

FIGURE No. 4

A skeleton soil. This profile shows a thin, coarse textured sandy soil over gravel, with low water retention capacity. Such soils are soon ruined if the surface is exposed to wind action. Hence they must be recognized as being unsuited to permanent arable culture.

SECTION III

SOILS: ROCKS, SURFACE DEPOSITS AND LANDSCAPE

(or the material on which soils are formed)

Why do soils vary in texture? Some areas are stony, other areas are stone-free, in one case the soil material may be coarse, in another it may be fine, in one place the particles may be sorted, in another they may be assorted, in some cases the soil minerals may be derived from limestone, and in other cases from shale, while yet in other cases they may be derived from granite, or more frequently, from a mixture of rock flour from any or all of these different rocks. Hence the soil texture may vary from coarse to fine, and the lime reserve in the minerals may vary from high to low. In other words, the surface deposits on which soils are formed vary in texture or in size of particles, and in mineral and chemical composition.

The general appearance of the landscape also varies. Here the land may be hilly, there it may be flat, here it may be rough, there it may be smooth, here it may be excessively drained, there it may be poorly drained. Because the configuration of the landscape and the mineral composition of the surface deposits on which the Manitoba soils have developed as the result of geological agencies that have been at work through the ages, it may be of interest to review the methods of deposition of the surface deposits and the rocks from which they were derived.

The configuration of the surface of Manitoba is due in part to the underlying rocks. The province is separated into two large surface areas by the Manitoba escarpment. This escarpment is the sharp rise of land which forms the Pembina and Tiger Hills, the Riding and Duck Mountains and the Pasquia Hills. East of the escarpment is the relatively smooth area often referred to as the first steppe, lying at less than 1000 feet above sea level. West of the escarpment is the area known as the second steppe which lies at altitudes varying from 1400 to 2400 feet above sea level. The surface of the second steppe is much more undulating and rolling.

If, in the second steppe area, wells are dug through the surface deposits to the underlying rock, it is found that the first bed-rock encountered is shale. This shale is formed from clay deposits, which through countless ages hardened into rock. There are a number of these shale beds lying superimposed one over the other, so that in some cases, their combined thickness may be several hundred feet.

If wells are dug in the area between the escarpment and Lake Winnipeg, the first rock generally encountered under the loose surface deposits would be limestone, but east of Lake Winnipeg, neither shale nor limestone rock would be found. In the latter area, rocks which are either granite or granite-like are to be seen out-cropping at the surface over a considerable portion.

If we could cut through Manitoba and expose a cross-section through the rocks from the east to the west, it would be observed that the granite and granitoid rocks (which form the surface rocks in eastern Manitoba), tip westward and form the floor on which all the other rocks rest. From Lake Winnipeg westward the granitic (or igneous) rocks are covered by limestone rocks, but from the Manitoba escarpment westward, the limestone rocks are covered by hundreds of feet of shale. Thus the rocks of the first or lowest steppe are either granite-like rocks or limestone rocks resting on granite, and the rocks of the second steppe are shales superimposed over the limestones which cover the igneous rocks.

Surface Deposits:

It is from these granitic, limestone and shale rocks that the surface geological deposits were derived. How these surface deposits were derived, and the methods by which the surface materials were transported and deposited, is a fascinating story.

Relatively late in the earth's history, a cold period known as the "Great Ice Age" occurred immediately previous to the present period. During this ice age, which lasted on and off for about one million years, more snow fell in the northern part of this hemisphere during the long winters than was melted during the short summers. Consequently, the snow piled up to enormous depths, and under pressure was changed to ice. A similar condition on a smaller scale occurs at the present time in Greenland. Greenland is covered by an ice cap which is about 1500 miles long, from 600 to 700 miles wide, and from 4000 to 8000 feet thick. Under normal surface pressure, ice is hard and brittle, but the enormous pressure resulting from the weight of hundreds of feet of ice causes the mass to flow or spread from the base. The icebergs off the coast of Labrador originate from this type of ice movement. These icebergs are large blocks of ice that have broken off from the Greenland glacier as it is pushed very slowly from the land into the sea.

During the glacial period an ice sheet covered the northern part of this continent, spreading southward as far as Montana, South Dakota, Iowa, Illinois, Indiana, Ohio, New York and the New England states. During the glacial age which lasted perhaps

a million years, glacial ice advanced and retreated several times, so that there were glacial and inter-glacial periods. It is estimated by geologists that the intervals between the respective retreats and advances of the ice sheet were longer than the period or length of time from the retreat of the last ice sheet to the present day.

The significant point from the standpoint of our present study is that during the last glacial period the enormous Keewatin ice sheet had its centre in the vicinity of Hudson Bay, from which point the ice slowly moved in all directions, modifying the surface over which it moved. The surface projections were either plucked away or smoothed and the rocks were scoured and streaked. Stones, fragments of rock, and rock flour which became embedded in the ice were moved as and when the ice moved, and later, were deposited as and when the ice melted. This mixed material, i.e., stones, sand and clay, transported and deposited by glacial ice, is called boulder till or glacial drift. (It can be recognized by the presence of stones embedded in assorted textured materials.) The boulder till thus derived was deposited as a covering of varying thickness over the rocks of the first and second steppe referred to previously.

In general, the thickness or the depth of the boulder till deposits in the western and southern parts of the province is greater than in the north-eastern portion. In the area east and north of Lake Winnipeg the glacial ice scoured down to the igneous or granitic rocks and left considerable areas with little or no surface covering. In the Interlake area there is some out-cropping of limestone rock but the rock over the larger portion is covered by boulder till derived largely from the limestone, and the admixture of material carried in from the igneous area. West and south of the escarpment the shale rock is more or less completely covered by boulder till which is here composed of an admixture of materials derived from shale, limestone and granite. This can be seen anywhere in the western and southern parts of the province where if the boulder till is examined, limestone and granitic rocks are to be seen embedded in a light khaki or creamy buff clay, intermixed with particles of shale. The light color of the till is derived from the powdered and decomposed limestone.

The various mixtures of boulder till were deposited by the glacial ice in two topographical or landscape forms which are very significant from the standpoint of land use. During the melting back of the last ice sheet the retreat was not continuous. For a considerable time the edge of the ice would melt as fast as the moving bulk was advancing, with the result that the margin appeared stationary. When this occurred, the debris, which was

carried to the point where the ice melted, accumulated as marginal deposits. These accumulations of material, which are known as terminal and recessional moraines, can be seen as chains of rough hills with knob and basin topography. Stony hills and gravelly hillocks associated with undrained basins containing sloughs or small lakes are found running across Manitoba at a number of points. These marked topographical features result from the morainic form of deposition.

Between the recessional moraines where the ice melted rapidly, the debris generally was deposited as undulating till plains. Here the boulder till is invariably much less stony and the surface is much more smooth.

Boulder till (either in the form of rough morainic hills or as relatively smooth undulating till plains) is found covering the rocks over practically all of Manitoba. On the higher altitudes the till deposits extend to the surface, but over a considerable portion, especially at the lower altitudes, the boulder till in turn has been modified or covered by stone-free deposits derived from the glacial drift.

It has been noted that the highest land in Manitoba is in the west and southwest; that the land falls from the second to the first steppe, and that the first steppe falls to the north and northeast. The surface drainage in the province therefore is toward Hudson Bay. During the time that the glacial ice was melting in the southern part of the province, drainage to the north was prevented by the enormous barrier of ice. Consequently, water became ponded as lakes over any depressed area where the fall was to the north. Such lakes, partly bounded by glacial ice, are known as glacial lakes. The highest of these lakes in Manitoba was "Glacial Lake Souris," which was formed in the southwest when the ice melted back as far as the Arrow Hills.

As the ice melted back from the Red River Valley and from the first steppe, an enormous lake known as "Glacial Lake Agassiz" was formed. The western shores of this lake can be traced by the gravel beaches along the Pembina and the Tiger Hills, the Riding and Duck Mountains and the Pasquia Hills. East of this shore line the surface of Manitoba has been profoundly influenced by this glacial lake.

The surface of the areas covered by the glacial lakes were affected in two important respects. First, when the waters drained away, the surface was left with a more or less smooth topography. Second, the boulder till deposits covered by the water were either sorted and modified by water action or they were buried under the sand or clay brought in by rivers and streams.

The modification of the surface deposits in the bed of these glacial lakes are manifest in many ways. Along the shore lines the sorting by wave action resulted in the removal of the finer materials, and in the accumulation of the coarse material (i.e., gravel and coarse sand), as beaches. Next to the gravel beaches the lake floor is invariably covered by varying depths of sand, whereas in the quiet waters of the deeper part of the lower lake basins, extensive beds of clay were deposited.

Running water also has played an important role in locally modifying the topography both of the till and the lacustrine deposits. During the formation of the terminal moraines there were times when large quantities of water were pouring from the melting ice. As these torrential waters rushed away, the boulder till was much sorted, so that local out-wash plains of sand and gravel were formed, while the finer particles were carried by the running waters to the rivers and lakes into which they emptied.

Running waters, as streams and rivers, have been active from the time of the recession of the ice sheet up to the present day. These streams eroded or carved ravines and valleys and carried the eroded material to be deposited elsewhere. In periods of high water and especially where stream banks are shallow, rivers have flooded and have deposited alluvium and fine sediments as flood plain material.

In addition to the surface deposits which have been laid down by glacial ice, or in lakes and by running water, there are also local areas which have been modified by wind. As the glacial ice sheet retreated and as the glacial lakes drained away, large areas with little or no vegetative cover were exposed to wind action. Consequently sandy deposits were blown into dunes. However, with time, vegetation covered the various deposits so that the surface became more or less stabilized.

The above broad outline is presented in an attempt to explain briefly the differences in landscape, and in the texture of the surface deposits on which the soils of Manitoba were formed. The landscape and the surface deposits are an open book, illustrated in color, which is given free for all (who have the seeing eye and the understanding mind) to read.

Questions:

1. In what portion of the province do rocks outcrop extensively at the surface, and why are the rocks exposed in some areas, whereas elsewhere they are buried under loose material?

2. How did the boulders in the soil of the prairies get there and where did they come from?

3. In the case of the soils which contain stone, why is it that in some districts the surface of the land is fairly smooth and in other districts the surface is rough or hilly?

4. Why is it that, in some areas, material containing stones is covered up by material which is free from stones?

5. What caused the gravel ridges east of the Manitoba Escarpment?

6. Why do sand dunes occur in some sandy areas but not in others?

7. Why is such a large area of the Red River Valley covered with clay?

8. When a farmer excavates a dugout, where does he put the material that was taken out of the hole; when Nature excavates a valley or a ravine by means of running water where does she put the material that is removed?

FIGURE No 5

The chief cause of soil deterioration in Manitoba is not the growing of crops, but the removal of soil by wind and water. The white knolls here illustrated show the extent to which the surface soil has already been removed and the productivity consequently impaired

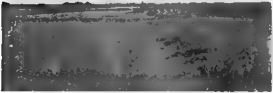


FIGURE No. 6

Soil deterioration caused by wind erosion due to lack of surface cover. Stones and cobbles left at the surface of the field to the left, sand trapped in Russian thistle to the right, and clay and finely divided organic matter lost in clouds of dust.

SECTION IV

THE SIGNIFICANCE OF THE SURFACE DEPOSITS AND THE LANDSCAPE

(or the effect of altitude, topography and texture of the surface deposits, and of drainage, on the climate of the soil)

Although the differences in altitude of the surface deposits in Manitoba are not very great, the differences are sufficient to cause some modification in the local climates. It should be borne in mind that the air currents in Manitoba generally move from west to east, and that as air rises it cools and as it falls it warms. From the western boundary of Manitoba to Riding Mountain the altitude rises from around 1700 to 1900 feet at the border to 2400 or 2500 feet at the top of Riding Mountain. Air moving in this direction to pass over the mountain cools, resulting in the cooler air climate which is so favourable for the growing of oats in that portion of Manitoba. From the Riding Mountain the land falls sharply eastward to an altitude of from 900 to 700 feet. Similarly, in the southern part of the province the land west of the escarpment has an altitude of from 1500 to 1700 feet, but it falls east of the Pembina Hills to from 900 to 775 feet in the Red River Valley. Due to the lower altitude, the warmer climate of the southern part of the Red River Valley is more favorable for the production of corn, melons, and orchard fruits than is land in the same latitude but at a higher altitude to the west of the escarpment.

These differences in altitude therefore exert a general effect on the air climate. At the same time, local differences in topography may affect the local soil climate so that differences may exist even within the same field. It is obvious that where water runs off the knolls and slopes, less water will penetrate into the ground and the soil will be locally dry. On the other hand, the rain which falls in the low position is supplemented by the water run-off from the higher land, and consequently the soil in the low position is subject to a wetter or more humid climate, where the soil is wetter it is also cooler. Hence, the climate (moisture and temperature) within the soil on the knolls, on the level, or in the low position will be different. The higher the knoll or the greater the slope, and the deeper the depression, the greater will be the differences in the local soil climates. Any difference in soil climate will be expressed both in the soil type and in the vegetation it supports.

It is also important to observe that some depressed areas have drainage outlets, so that the soil may be fairly well drained, in

which case the soil climate will more nearly approach the normal. Other depressions are closed basins from which there is no outlet, and, as drainage is retarded, wet or water-logged conditions result.

The two different aspects of drainage should not be confused (i.e., surface drainage, and internal drainage). Surface drainage is controlled by slope and topography Internal drainage refers to the ability of water to percolate downward without obstruction.

The moisture and temperature within the soil is also affected by the texture and porosity of the soil and of the deposits on which the soil is formed. In the case of sands, rains penetrate freely, and sands are usually porous. As the water retention capacity of sands is low, the greater portion of the rain percolates through the sand until it reaches some less porous or more impervious sub-strata. When downward movement is retarded the water fills in the air spaces and forms a water table or plane of saturation.

In the case of clays or heavy textured soils, water from precipitation does not penetrate as freely as in the case of sands. Moreover, the water retention capacity of the heavy textured soils is greater, and so the heavy soils are relatively moist and cool, whereas sands (if well drained) are relatively dry and warm. The relative water retaining power of the different textured soil materials can be appreciated if one remembers that under free drainage, the amount of water available to plants which can be retained to a depth of one foot by sands is from one-quarter to one-half inch, sandy loams will retain from one inch to one and one-half inches; loams will retain around two to two and one-half inches, clay loams around three inches; and clays around three to three and one-half inches.

It is obvious therefore that altitude, topography, slope, exposure, drainage and soil texture, separately and collectively, may have a marked influence on the local soil climate and on the local soils.

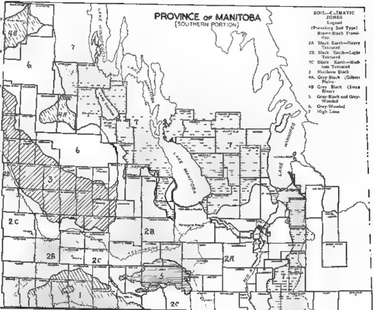
The air climate and the soil climate are reflected in the native plants which are found growing on the various sites under virgin conditions. Differences in regional climate (that is, the climate of the region as a whole), is indicated by the grass vegetation of the prairies in the southwestern portion of the province; by the forest vegetation in the more northern and eastern portion of the province; and by the park-like aspen-grove area that occurs as a transition between the forests and the grassland. Within each climatic region local variations in soil climate are reflected by differences in vegetation. In the aspen-grove region, grass occupies the drier sites, and woods and meadows occupy the more humid

sites. In the forest region, dry grassland areas indicate either the presence of gravel or rock, and tamarack or swale grasses indicate swamp or peat. In the grassland region the drier sites are indicated by the more sparse growth of grass and associated herbs, and the locally humid sites are indicated by alkali tolerant types of vegetation or by alkali meadows and sloughs.

Our studies have attempted to bring out the fact that soils are the result of the interaction of climate, vegetation and the mineral material on which the soils are formed also because climate, vegetation and parent material are variables, soils are variable. Regional soils develop where regional factors are dominant, and local soils are developed where local conditions prevail. Therefore, if we examine the soils in a given municipality, township, or section, we may find different soil types. The differences in the respective soil types found in any position, in the final analysis, are the result of the varying determining factors which may be enumerated as (1) the climate, or temperature and moisture within the soil, (2) the mineral material on which the soil is formed; (3) the vegetation under which the soil developed; (4) the position of the soil in relation to topography, (5) the internal drainage; (6) the age, or the length of time that the material has been acted upon by the soil forming process, and (7) in the case of cultivated soils, the effect of culture or the work of man.

Questions:

1. Do the differences in altitude which occur in Manitoba affect or modify the climate (or weather) in local districts sufficiently to influence the type of land use and the crops that can be grown?
2. Why was the native vegetation different in different parts of the same district?
3. If the native vegetation was different under virgin conditions, should we expect the cultivated crops to be uniform after the land is broken up?
4. Why are different soil types found on the same farm?
5. What are the different soil types that occur in your district, and are the differences in types sufficient to influence the type of land use?


PROVINCE OF MANITOBA
(SOUTHERN PORTION)
SOIL—CLIMATIC ZONES
Legend
(Prevailing Soil Type)
Brown-Black Transition
2A Black Earth—Heavy Textured
2B. Black Earth—Light Textured
2C Black Earth—Medium Textured
3 Northern Black
4A. Grey-Black (Gilbert Plains)
4B Grey Black (Swan River)
5. Grey-Black and Grey-Wooded
6. Grey-Wooded
7 High Lime
LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE DAUPHIN
LAKE WINNIPEG
ASSINIBOINE
RED R.
4B
4A
2B
2C
2A
3
5
6
7
1

SECTION V

SOIL ZONES OF MANITOBA

Though many different soil types can occur in a given municipality or township, the well drained soils in any district tend to resemble each other in certain important characteristics and in their land use possibilities.

The common characters of the well drained soils are due to the fact that they are determined primarily by regional climate. Therefore the province of Manitoba can be divided into soil zones on the basis of the common characteristics of the well drained soils. (Soils which differ from the zonal or regional soils are the result of local factors, and they must be considered as local or intra-zonal soils.)

The common characteristics of the zonal soils are not only the basis of classification, but they provide a useful guide to soil adaptation and use.

The soils of the grassland region are the most valuable from the standpoint of present day agriculture because of their general high fertility and their high organic content. These two characteristics are the result of the climate and the grass vegetation under which they were produced. The grasses not only provided the means of subsistence for the lordly herds that roamed the plains in by-gone days, but because of the contribution they made to the development of the fertile soils of the Manitoba prairies, these grasses provided a legacy from which benefits are derived at the present day. Under the virgin grassland, the mineral matter and the organic matter combined to form the good black earths, famed for their high organic content, for their high nitrogen, and for their granular structure, friability and productivity.

The fact that the general cover was grass rather than trees, indicates that the climate was too dry for forest growth, but was sufficiently moist for the production of the prairie and steppe grasses. Moreover, one of the characteristics of the grassland soils, is that an accumulation of lime carbonate occurs just below the dark colored surface soil. The presence of this lime layer shows that the amount of water entering the soils is not sufficient to cause the lime to be carried down into the ground waters. Thus because of climate through the ages, organic matter, nitrogen, and lime have accumulated in the grassland soils so that they are neutral in reaction, high in organic matter, and highly fertile. In these soils production is controlled chiefly by the availability of moisture.

Within the grassland region three soil zones occur (1) the brown-blacks, (2) the blackearths, and (3) the northern blacks. These were formed as a result of differences in moisture and temperature.

(1) Where somewhat drier conditions prevail in the southwestern portion a soil zone designated as the brown-black or dark brown-blackearth transition soils occurs. The brown-black soils are primarily adapted to the production of high quality wheat. Their high fertility makes them suitable for the production of any crop which can be grown in the prairie region providing that sufficient moisture is available, but as this zone is subject to the periodic occurrence of drought, the soils are best suited for the production of wheat as the major enterprise, with other types of agricultural production subsidiary and supplementary

(2) The larger portion of the grassland region in Manitoba is occupied by the black-earth soils. The black-earths are exceptionally high in organic matter, so much so, that the nitrogen content in the better textured virgin soils may be as high as in barnyard manure. The lower depths to the lime layer, together with the higher organic content, indicates that the moisture conditions are more favorable for crop growth. These black-earth soils can be used for the production of a wide range of crops. Grains, grasses, legumes, corn, potatoes, roots, vegetable and many other crops can be depended on to give satisfactory yields under good management in most seasons. Hence, any type of farming could be followed where the textures are good, and where stone or locally impeded drainage does not interfere with cultivation. The fact that the black soils have been used so largely for grain production in the past has been due to economic conditions, they could support a much larger population if markets were available for diversified products.

(3) The northern black-earth soil zone occurs in the northern portion of the prairie region, where groves of aspen and woodland invasion of prairie proclaim a higher humidity than is common in the more open grassland plain. These soils are also highly fertile, but because the soil climate is cooler and more humid, these soils produce wheat of high yields, but of somewhat lower protein content. This zone is exceptionally good for the production of barley and oats, and somewhat better than average yields of grasses, legumes, roots and potato crops can be expected. These soils also have a much wider adaptation to different types of farming than is being practised, but again, because of the difficulty of disposing of other types of produce, the arable land has been used largely for grain production with mixed farming supplementary to the major enterprise.

To the north of these three soil zones other soils have been developed under grassland or under tree invasion of prairie which occur as islands within the forest region. The good black-earth soils of these intra-zonal areas (such as those occurring in the Dauphin district and the Swan River Valley), have similar adaptation to the northern black-earth soils.

With a few exceptions, these soil zones and the intra-zonal islands of similar soils already mentioned, account for practically all the land used for agriculture in this province. It is of interest to note however, that, of the land held as farms, only one-half is under the plow at the present time. A large portion of the remainder is affected by local conditions resulting in local soil types which are of less value for the production of grain.

North of the prairie and aspen grove region is a vast expanse of soils developed under forest. Here the higher moisture efficiency of the climate has resulted in the development of forest soil types which differ markedly from the grassland soil types. The surface soils below the leaf mat are low in organic matter, and because more moisture passes through the soil than is used by the plants or lost by evaporation, the products of weathering tend to be leached from the surface (except where the forest has developed on material of limestone origin). Hence the surface soils of the forest region are not normally as highly fertile as are the soils of the plains. This does not mean however that they are infertile. The more favorable moisture conditions not only favor the growth of trees, but also insure that high yields of grasses, legumes, roots and coarse grains can be obtained, provided that the fertility and organic matter requirements are satisfied. Types of agricultural land use can be developed in future years which would enable the better soils to support a large population.

In the forest region there is an intra-zonal area between Lake Winnipeg and Lake Manitoba where soils have developed on high lime geological material, much of which is either too stony or too wet for arable culture, but which may be used for dairying, livestock, and forestry. Scattered throughout the limestone area are local soils which are valuable for the production of alfalfa seed and for mixed farming. The failure to develop the arable soils in this sub-zone has been due in large measure to a lack of understanding of their character. These young, feebly developed soils are characterized by a high lime condition, shallow depth, and low availability of phosphorus. The growing of legumes, and the use of manure or phosphate fertilizer, would make certain types of agriculture practicable if markets could be obtained for diversified products.

By far the larger portion of the forested region awaits further development. Nevertheless the virgin soils of the forest region are producing natural resources which annually add to the wealth of Manitoba. It may be of interest to recall, that the rich harvest of furs in the forest region attracted men to Manitoba, long before the rich stores of fertility in the black-earth soils were required to provide, for many millions, the answer to the Galilean's prayer for daily bread.

To the north of the forest region, and beyond the timber line, the soils continue north and east to the shores of Hudson Bay. Here, even with an ever frozen substratum, the tundra soils are far from barren. They produce (to the limit of the climate) a growth of sedges, grasses, herbs, lichens and mosses. The extent to which these can be utilized is a problem for future years to solve.

Questions:

1. What are the agricultural problems and the agricultural possibilities of the typical well drained soils in the three major soil zones of the grass-land region?
2. What are the land use problems and agricultural possibilities of the forest region?

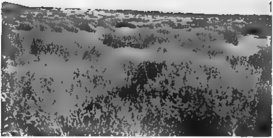


FIGURE No. 8

A farm in South Western Manitoba, with ground water six feet below the surface abandoned because of soil drifting.

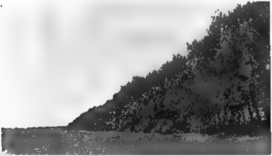


FIGURE No. 9

A farm in South Western Manitoba, on similar textured soil to that in Figure No. 8, protected by field wind break.

SECTION VI

SOIL PRODUCTIVITY AND AGRICULTURAL PERMANENCY

In the production from the soil of the crops required for man and beast, the farmer plays his part in the marvel of creation which is repeated season after season. As each crop is harvested, bare fields are exposed which present a new challenge: a new opportunity for preparation and sowing, a new chance to work with and in some measure direct, the forces of nature to produce a new, glorious creation. Hence the wise farmer will study the natural objects and the forces with which he has to work, so that he may plan intelligently and work wisely.

Crop production in any one season is not the result of one, but of many factors. The crop harvested is determined primarily by the soil, the climate, and the seed or kind of crop, but in addition it must be noted that the maximum returns which might have been secured from the seasonal combination of soil, weather and crop, may have been profoundly modified by the presence of weeds, insect pests, and plant diseases.

The farmer can choose the crop that is to be grown, and insofar as he controls weeds, insect pests and plant diseases, he protects the crop from injury and thus permits it to make the maximum use of the moisture and nutrients available in the soil under the limitations of climate. Atmospheric climate under field conditions is a variable and is out of man's control. The farmer must take the weather as it comes and make the best of it. However, he can and must adapt the general agricultural system to the average climate.

The soils on which the crops are grown are also variable; but in the final analysis it is the condition of the soil which determines the potential productivity or the cropping possibilities, provided of course that the crops sown are suited to the region, and good husbandry practices are followed.

What constitutes a fertile soil? A soil is fertile and productive if it provides favorable conditions for plant growth and satisfies the plant requirements for normal development. These requirements may be listed under a few headings as follows:

(1) The soil must provide a satisfactory medium for the development of the roots which are the plant's intake system.

(2) The soil must provide the plants with water, but at the same time the soil must be reasonably well drained.

(3) The soil must provide the plants with the mineral chemical elements required as nutrients.

(4) The soil must have a favorable reaction, that is, it must be neither too acid nor too alkaline, and in addition, it should not contain an excess of toxic or injurious substances.

(5) The soil must be reasonably free from soil borne diseases.

(1) The soil as a medium for root development:

The roots are the intake system of a plant. Hence a fertile soil must be of sufficient depth and be in such condition that the plant can develop a satisfactory root system. The greater the depth of soil, the greater will be the possible feeding range. This may be appreciated if it is remembered that the roots of the annual cereal crops extend to a depth of three to four or more feet. Perennial crops like alfalfa will require from eight to ten or more feet of depth for root room. The presence of rock, hard-pan, or dry lenses (layers) of gravel may be responsible for a shallow depth of soil and for the restriction of root room. Moreover, even though the depth of soil may be satisfactory, root development within the soil may be affected by the texture (or size of the soil particles), by the structure (or arrangement of the particles into aggregates), and by the friability and permeability of the soil mass. If the soil is coarse (or sandy) in texture, plants cannot develop such a fine network of roots as they can in a loam or a friable clay loam soil. On the other hand, if the soil is a heavy waxy clay with feeble structure, the pores between the particles may be so fine that root development is restricted. Such a heavy textured clay soil also may break or prune the plant roots as the soil shrinks on drying. It also should be noted that roots develop in moist soils, they will not develop in or pass through a dry layer. Consequently root development may be restricted by a temporarily dry sub-soil.

The growth of a plant is influenced by its intake system. The intake system (i.e., roots) of the plant is influenced by the condition and depth of the soil.

(2) The soil must supply the plant with water:

Plants through their intake system obtain water from the soil, but it must be remembered that it is only the water which enters into and is retained by the soil that can be used by plants. The seasonal precipitation on a given field for example may be 13 inches, but all of this is not available to the crop. Some of the precipitation falls in such light amounts that it is intercepted by the leaves and evaporates back into the air without entering the soil at all. Moreover, the rain that falls faster than the soil can

absorb it will run off, and the greater the slope, the greater will be the run-off. Also more run-off will occur where the soil is less porous. Thus, only a portion of the seasonal precipitation may enter the soil.

Water which enters the soil will penetrate to different depths depending upon the soil texture. We have seen in a previous section that a sandy soil will retain only from one-quarter to one-half inch of available water per foot, sandy loams will retain one inch of available water per foot, fine sandy loams, one and one-half to one and three-quarter inches, loams, two inches, clay loams, three inches, and clays three and one-half inches of available water per foot depth of soil. Expressed in another way, if three inches of water entered a well drained clay loam soil it would wet the soil to a depth of about one foot, but if three inches of water entered a sandy soil it would moisten the soil to a depth of two and one-half to three feet. It is obvious, therefore, that different textured soils have a different ability to supply plants with water. If the water retention capacity of the different textured soils is kept in mind, and if we assume that a twenty five bushel crop of wheat and straw will take from the soil a little more than eight inches of water, it is obvious that even by the best system of summer fallow, sufficient water cannot be stored in the light textured soils to supply the needs of the crop through a long continued period of drought. This is why the light textured soils are droughty and of low value in regions of limited precipitation. In semi-arid regions the heavier textured soils are invariably the more productive because of their higher water retention capacity.

(3) Soils must supply the plant with nutrients:

Plants are complex organisms, designed by nature to build up their own tissues and the compounds which are referred to as starches, sugars, plant proteins, etc., from the chemical elements which are found in the air and in the soil solution. The bulk of the plant material is made from carbon, hydrogen and oxygen which are derived from air and water. Plants also require nitrogen, but with the exception of legumes (which can obtain nitrogen from the soil air by the aid of the bacteria which live in the nodules on their roots), all plants obtain their nitrogen from the soil. Nitrogen in the soil is contained in the soil organic matter. As a general guide it may be taken that one-twentieth of the soil organic matter is nitrogen. Therefore if the organic matter is high, as it is in the black prairie soils, the nitrogen also will be high, but if the organic matter is removed from the soil by wind erosion the nitrogen also will be removed. However, because the nitrogen of the soil is fixed in complex organic compounds it is not

available to growing plants until the organic matter is acted upon by organisms and the nitrogen released in an available form.

We have seen in a previous section that the activity of the soil micro-organisms is controlled by climate (temperature and moisture). Hence the availability of nitrogen in the soil to plants will depend upon the activity of the micro-organisms, which in turn depends upon the weather conditions. A soil may be highly fertile as far as being able to supply plants with nitrogen if the soil is warm and moist, but the same soil may be deficient in available nitrogen in a cold backward spring.

The other elements required by plants are mineral elements that are derived from the soil. They include phosphorous, potassium, calcium, magnesium, iron and sulphur, and in some cases traces of such elements as manganese, boron, zinc and copper. These elements are derived originally from the soil minerals, but a portion of such elements as phosphorus and sulphur may be combined with the organic matter of the soil. Mineral elements which are combined in the organic matter are liberated when the organic matter is acted upon by the soil micro-organisms.

A chemical analysis may show the total amounts of chemicals contained in the soil to be high, but the important point from a fertility standpoint is how much of the chemical elements are available to the plant. In humid regions, the downward moving water tends to leach the so-called available nutrients out of the soil. In the prairie soils of Western Canada this depletion of the available nutrients by leaching is not an important factor. In the prairie region the occurrence of drought is more of a problem than is the leaching out of the nutrients by an excess of water.

As a general rule, soils with finer textures are better able to supply the plant with mineral nutrients. Sands and the coarse mineral fragments are inert and play little or no part in plant nutrition. From a plant nutrition standpoint the organic matter and the clay are the important constituents. If the organic matter and the clay are removed by wind in the form of dust the soil is impoverished.

(4) Soils must have a favorable reaction:

Cereals and many other agricultural crops will grow in soils which range from slightly acid to slightly alkaline, but for best results the soil should be neither too acid nor too alkaline. Acid soils however are not a problem in the prairie region of Manitoba. Soils which are so acid that they require the addition of lime for the correction of acidity occur in moist humid regions, not in the

semi-arid regions. Sometimes a person will refer to a soil as acid when he means that the soil is wet and poorly drained, but this is a wrong use of the term. A more common problem found in the semi-arid region is soil alkali. Acid soils occur where the mineral elements are leached out of the soil, but alkali soils occur when the mineral salts derived from weathering accumulate in the soil (either because there is not sufficient water to wash them downward or because the run-off water accumulates in the depressions where it later evaporates). An excess of soluble alkali salts is injurious to plants, but some salts are more toxic than others.

In Manitoba, the soils which contain an excess of alkali salts usually occur as a result of the accumulation in the soil of water containing soluble salts, such soils have either impeded drainage or were formerly poorly drained. Well drained soils in Manitoba are rarely ever saline.

(5) Soil should be reasonably free from soil borne diseases:

If the physical condition of the soil is satisfactory for root development, if the soil is moist, if it can supply the mineral nutrients required by the plant, and if the soil solution is not toxic, such a soil will be fertile, but although these conditions may be right, the presence of certain soil borne diseases may sometimes be responsible for the failure of a soil to produce certain crops satisfactorily. The presence of flax wilt or root rot are examples of such soil borne diseases which may be responsible for poor returns from soils containing these diseases which would otherwise be rated as fertile soils. Such soils might be quite productive if measured by different crops which are not subject to such diseases.

If the soil fulfills all the above requirements it can be classed as a fertile soil.

Can soils be kept fertile?

To ascertain if the system of agriculture or the cropping system is a permanent one designed with a view to maintaining soil fertility, it should be measured by the following rules:

(1) Does the system make provision for an adequate supply of water for the plants?

(2) Does it make provision for the supply of nutrients removed from the soil by cropping, etc?

(3) Does it make provision to maintain the organic matter for keeping the soil in a good physical condition?

(4) Does it prevent the removal of soil or soil material by wind erosion or the washing away of the soil by water erosion?

(5) Does it make provision for the control of weeds, insect pests and plant diseases?

If the system of soil management provides for all these things, then it may be considered that as far as the soil is concerned, the system provides for agricultural permanency

Questions:

1 What are the six factors that determine the crop yields in any one year and how many of these are under the control of the farm operator?

2 What is it that crop plants require from the soil?

3 How may we know if the method of crop and soil management that is followed will keep the soil permanently productive?

FIGURE No. 10

Water erosion on a Manitoba farm. Surface soil in process of removal from the higher to the lower levels

FIGURE No. 11

Shoe-string gullying on a Manitoba farm. Cultivation up and down hill accelerates erosion. This type of erosion is a warning signal that a change in management practices is urgently needed if disaster is to be avoided.

SECTION VII

SOILS: WHITHER AND HOW

In a previous section, under "What and Where," we have tried to discover what soils are and where they are found. In another section we reviewed the purposes for which the soils of Manitoba are used. We noted in connection with arable land use that there was first a pioneer period of expansion that lasted for about one-third of a century, following which the acreage of arable land remained more or less static for the next twenty-five years. During this period, the prevailing arable land use consisted of a system of fallow-grain cropping, with an appreciable amount of livestock kept as a supplementary enterprise but supported in a large measure on the unbroken lands.

What has been the effect of the past and present system of land use on the arable soils of Manitoba, and what of the future? Will the soils continue to be productive? Where are we heading? What modifications in soil management, if any, are required? In other words, after reviewing the "What and Where" we must face the problems of "Whither and How."

In the preceding section, under the sub-heading, "Can soils be kept fertile?" a number of questions were listed (Pages 35-36). These may be used by each farm operator as a measuring stick to ascertain if the management practices followed are sound from the standpoint of agricultural permanency. These questions are a challenge. They should be studied and carefully considered before any attempt is made to answer either yes or no, and they must be answered, not carelessly from wishful thinking, but honestly from recognition of the facts. The answers, if honestly given, will show the ultimate effect of the present methods of management on soil productivity, and they will indicate the modifications in management practices required on each individual farm. In this study-section we can present only a generalized outline, each study group will have to sketch in the local details.

Before proceeding, however, two points should be disposed of. The first is that the class or type of farming followed does not guarantee permanency of soil productivity, and the second is that the submarginal soils should be eliminated from attempts at permanent culture.

Class or Type of Farming:

The various types of farming may be classed generally as grain growing, diversified or mixed farming, truck farming or market gardening, specialized livestock or dairy farming, and

ranching. Any of these types of agriculture may be permanent or transitory, depending upon the care with which the soils are husbanded. Persons who do not understand either our soils or the regional conditions, are prone to jump to the conclusion that grain growing is wicked, that more livestock must be kept, and that the only ideal is some mystic ritual designated as "mixed farming." Such conclusions are not necessarily correct. For example, what difference is there in the effect of cropping on soil fertility in the case where grain is shipped off the farm and the straw burned, and in the case where grain and straw are removed, fed to cattle, and the manure thrown down the river bank? Even where the manure is saved and applied to the soil how many men in Manitoba have manured all the farm once in a "lifetime?" It is obvious that it is not the type of farming, but the type of soil management that is important. Any one of the above-mentioned types of farming could be permanent if the practices followed measure up to the standards we have outlined. (See questions on Pages 35-36)

Submarginal Soils:

In planning the present and future land use policy, we must know our soils, we must recognize their possibilities and limitations. For example, it is important to recognize that shallow soils with rough topography (which are droughty because of excessive run-off), and coarse textured soils (such as coarse sands and light soils with gravelly sub-strata which have low water retention capacity), are submarginal for continuous arable culture in semi-arid districts. Attempts to farm such soils in the prairie region are doomed to failure. Hence submarginal soils should be taken out of arable culture and seeded down to grass, or planted to forest, or given other suitable treatments so that they may be used as assets—not carried as liabilities. It is highly desirable that lands which are not suitable for arable agriculture should be so designated, and that an administrative policy be evolved to prevent exploitation by private interests, and to avoid disappointment and ruination of the uninitiated.

If the principle of retiring sub-marginal soils from culture is recognized, then individual and community action becomes a duty. Further, we should appraise or evaluate a soil on the soil characteristics and the long-time average returns, not on the peak production in an abnormally favorable season.

The Problem of Agricultural Permanence in Semi-Arid Regions:

It may be profitable to recall that the agriculture of Western Europe was developed under favorable moisture conditions.

Through centuries of time stable systems of agriculture were developed as men learned to solve the regional problems. By practical experience they established certain principles of good farming that were effective in the regions they inhabited. Moreover, when people who had inherited the culture of Western Europe came to Eastern North America they found a humid climate where the agricultural principles of the old world still held good. Later, when migration headed farther to the westward, new regions were opened up which were not humid, but semi-arid, and consequently new problems were discovered more akin to those of the Russian Steppes. The problems of maintaining agricultural permanency in the old world under humid conditions were concerned largely with the maintenance of fertility. These problems were caused by the leaching of lime and of plant nutrients from the soil as the result of high rainfall. The new problems in the newly opened up, semi arid region of the west, on the other hand, were concerned with insufficient moisture as the result of precipitation deficiency. Hence, it is obvious that the agricultural practices, based on the principles of maintaining fertility under humid conditions, failed when applied to relatively fertile soils under semi-arid conditions, where the problems are physical rather than chemical.

During the history of the race, human beings have adapted themselves to a wide variety of conditions, but it is significant that permanent systems of highly developed agriculture and stable civilization have been developed only on certain soil types. It is pertinent therefore to ask, "Have permanent systems of agriculture ever been developed in countries where the climate is semi-arid?" The plains of Western Canada and Western United States, Australia, South Africa and South America have been settled only for a short span of years, and here large areas are semi-arid to arid.

Despite the relatively short period of agricultural history in all these newly settled countries, the question of soil deterioration is already causing grave concern to the respective governments. In Manitoba we have only to look around to see forms of soil deterioration similar to those causing concern in all the countries just mentioned.

These include:

(a) A general increase in the susceptibility to soil drifting.

(b) The removal by wind erosion of organic matter and clay from mixed textured soils so that they tend to become coarser and lighter in texture;

(c) The excessive piling up of soil and sand on fence-lines, headlands and roadways;

(d) The development of a pitted surface on light textured soils due to blow-outs and sand banks;

(e) The removal (by wind and water) of soil from hillocks and knolls so that exposed areas of light colored subsoils increase year by year;

(f) The gradual thinning of certain of the heavier soils due to the removal of surface material by wind or by water;

(g) The loss of soil from the slopes by sheet and rill erosion, and by gullying during heavy rains;

(h) The deposition of surface soil at the foot of slopes;

(i) The silting up of drainage ditches, dug-outs and catchment basins.

These signs, together with

(j) A marked lowering of the organic content in certain soils;

(k) Gradually decreasing yields; and

(l) An increase in the acreage of abandoned land,

are all indications of the deterioration which has already progressed locally to serious proportions.

It is obvious that these signs of deterioration are not all equally important in all soils. Some soils (such as those of light texture or of rough topography) are much more susceptible to injury under continuous cultivation than others. Nevertheless, whenever such signs are observed they should be considered as warning signals and as indicators that prompt action is required if disaster is to be avoided.

If we are to establish a permanent system of agriculture and prevent the extension of these signs of deterioration in Manitoba we must solve three major problems, i.e.:—

A. The combating of drought;

B. The control of soil erosion by wind and water; and

C. The maintenance of soil organic matter and of plant nutrients at satisfactory fertility levels.

A. The combating of drought:

As pointed out in the discussion of the soil zones, droughts are common and often severe in Manitoba in the dark brown-black-earth transition soils. They may occur occasionally in the black-earth and northern black-earth zones, but in this case they

are not usually of such long duration or of such great severity. They may occur however, but with less severity, in other portions of the province.

The source of water for agricultural use is precipitation, but the amount of water which a region receives in any year depends on factors which are out of the control of man. The entire approach to the combating of drought therefore must be through the conservation of water received. Water conservation implies judicious use with the avoidance of waste, or, in other words, water conservation is the intelligent organized control of the available water received, and its storage for maximum utilization by intelligent use.

An all-around policy of water conservation for the alleviation of drought requires action by the state, by the community and by the individual. The conservation of the regional supply of water in lakes, rivers and streams, etc., is the duty of the state, but it must be recognized that the storage of water in drainage channels or catchment basins, does not put water back into the soils of the fields from which it was derived by run-off or seepage. The control and storage of water must first start where the water falls, i.e., on the fields. Hence the adoption of water conservation practices by the individual is the first essential step in the combating of drought.

At the same time, in a schematic water conservation policy, governmental or co-operative activities should be directed towards preventing run-off on the non-arable land by maintaining and extending forests for water conservation (where trees can be grown) on the higher altitudes, on the slopes of ravines, on run-ways and on waste land; to the control of the headwaters of streams by check dams, and to the impounding of run-off waters by dams and reservoirs; to the regulation of stream flow, and to the organization of community conservation schemes.

In soil areas which are subject to drought, the farm operator should keep in mind the following objectives, all of which have to do with the conservation and wise use of water:

(1) The production on the farm of as much of the subsistence for the farm family as possible;

(2) The provision for subsistence for the necessary livestock;

(3) The provision for the combating of drought on the cultivated fields.

(1) The production on the farm of as much of the subsistence for the farm family as possible:

Subsistence for the farm family involves the growing of garden crops and the keeping of sufficient stock for home use, thus reducing the cash outlay for necessities in drought years when there may be little or no cash return. Both gardens and stock require adequate supplies of water. To secure this objective the water conservation work required is the installation of dugouts (where well water is not obtainable) or of dams in the run-ways to impound run-off water for domestic or stock use, and for the irrigation of gardens.

Dugouts or water impounding schemes should be large enough to ensure a good reserve of water for the irrigation of gardens if and when required. The excavated earth from the dougouts may be removed and used for the construction of low dykes around the garden areas and these dykes should be seeded down to grass.

(2) Provision for subsistence for the necessary livestock:

Feed for the necessary livestock is also dependent upon water, but in this case the water must be supplied by the soil. The cultivated acreage devoted to the production of feed on the average farm is often inadequate. Where stock is kept in the drier districts the acreage of grass and legumes should be increased, but as these crops may fail, an acreage of corn, millet and winter rye should be sown to ensure feed in quantities that will provide for a carry-over of cured fodder or ensilage. To produce such feed crops soil moisture is essential. Hence in dry districts and during dry periods it may be necessary to grow these crops on fallow. In semi-arid regions the principle of giving first place to the production of subsistence should be adopted.

(3) Provision for the combating of drought on cultivated fields:

After making provision for food and water for the farm family and the livestock, the farmer's activities should be directed to the combating of drought on the cultivated fields. Four objectives should be kept in mind.

(*a*) The prevention of run-off from the surface and the storage of precipitation in the soil.

This objective can be secured during the fallow year by keeping the soil receptive and porous at the surface. The latter involves some form of tillage immediately after harvest as well as during the fallow year. (See also water erosion.)

(b) Holding as much water as possible in the soil until required by the crops which are to be grown.

This objective can be secured by preventing weeds from using undue amounts of water from the time one crop is harvested until the time the next one is sown. It is essential that the water which penetrates into the soil will not be used by excessive growths of undesirable plants. Dead weeds and trash on the surface aid in the conservation of water, but living weeds exhaust the soil water supply.

(c) The planning of a fallow frequency so that crops are sown only when a reasonable supply of soil moisture is present.

This objective can be secured if a field examination of the soil is made in the spring by each farm operator. (Such examination may be made with a post hole auger or by digging.) The condition of the subsoil to a depth of four feet, whether moist, intermediate, dry or powder dry, can be ascertained from such a field examination. Thus, a field should be cropped or summer-fallowed according to the moisture condition of the subsoil.

(d) The prevention of the surface of the soil from drifting during the fallow or moisture storage period.

This objective can be achieved by maintaining a cloddy surface in the case of soils which still retain their power to form structural aggregates, or in the case of loose-topped structureless soils by maintaining a trash cover and by providing wind protection. (See wind erosion.)

B. Control of soil erosion by wind and water:

I. Wind Erosion:

Wind erosion is by far the most powerful agent in reducing the fertility of the soils of Manitoba. The main cause of soil drifting is the occurrence of winds of sufficient velocity to move the soil particles; the second cause is the presence of particles or aggregates of such size that they can either be rolled or lifted by the wind and carried by air currents. The methods for the control of erosion by wind therefore must be directed towards:

(1) The reduction of wind velocity or the providing of cover so that the soil is not exposed to wind action.

(2) Increasing the size and stability of the soil aggregates.

(1) Reducing wind velocity:

The common methods of reducing the velocity of the wind over the surface include the use of field wind-breaks, the maintenance of trash cover, and the use of fallow substitutes such as corn or other tall-growing annual crops sown either in blocks or in strips.

On light textured soils, black summerfallow should be avoided and unless a trash cover can be maintained, fallow substitutes should be used. On light soils also community projects in the planting of field wind-breaks should be extensively undertaken. Moreover, in the wooded and aspen grove areas, use should be made of the native woodlands for wind protection. The wholesale clearing of woods on light soils should be prevented and strips of native trees and shrubs should be retained for the protection of the cleared spaces, which (if possible) should be long and narrow.

(2) Increasing the size of the structural aggregates:

In the cultivation of soils which predispose to drifting, care should always be exercised in the use of tillage implements. Implements which pulverize the soil to powder should be avoided, cultural implements which tend to leave the surface in a roughened condition should be used, and the speed of travel in the case of tractor-operated machines should be controlled so that undue pulverization is avoided.

Any soil which is in a powdery or single grain condition will drift when exposed to wind action. Large aggregates on the other hand, are not moved by wind. The longer the soil has been under cultivation the more easily will the soil aggregates break down. Soil structural aggregates (or clods) are formed by the cementing action of the finer particles and by the binding action of grass roots. (The roots of cereals decompose rapidly.) When the ability of the soils to form aggregates is reduced due to the decomposition of the grass roots, and to the removal of the finer materials by wind, the soil should be temporarily retired back to turf-forming grasses or to grass mixtures. However, it should be noted that in the case of sandy soils, from which the finer material has been removed to the point where the soil becomes single grained, the seeding down to grass will not cause the development of aggregates which will resist the disintegrating action of wind. Hence the periodic retirement of arable lands to grass should be undertaken before drifting becomes acute and before the fine materials responsible for the cementing of soil aggregates have been blown away.

Soils on which drifting cannot be controlled by the above practices should be retired permanently or semi-permanently to grass or to other vegetative cover and used for other purposes than grain production.

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II. **Water Erosion:**

The erosion of soil by water is becoming acute in certain portions of Manitoba. Water erosion, like wind erosion, accelerates with time. Soils which have stood up fairly well against erosion in the years following the breaking of the prairie sod are now beginning to show evidence of this form of deterioration. Obviously, water erosion is more acute where the topography is rough. In certain parts of the province, lands have been broken that are too steep for arable culture. These lands should be put back into forest or seeded permanently to alfalfa or grass. On the lands which are not too steep for arable culture the following practices may be used to control erosion of the soil by water:

(1) The cultivation crosswise of the slopes instead of working up and down grade,

(2) The maintenance of a rough, cloddy and porous surface, or the maintenance of a trash or crop cover;

(3) Stripping of the slopes with buffer strips of grass at intervals along the contours;

(4) The installation of shallow broad base terraces and spreader dykes on the stronger slopes;

(5) Contour farming under crop rotations in stripped fields;

(6) The use of crop rotations which include the periodic seeding down to mixtures of grass and clovers,

(7) The seeding down of sharp knolls and steep slopes of ravines to grass or forest.

(8) The sodding of waterways and the control of the water by the use of check dams.

In the past little attention as been paid in Manitoba to these methods of preventing soil deterioration, but a vigorous policy of soil and water conservation, individually by land operators, and collectively by agricultural organizations and by the provincial government, is urgently needed. The control of the mechanical causes of soil deterioration is a challenge to the people of Manitoba.

C. **Maintenance of the Soil Organic Matter and Plant Nutrients at satisfactory levels:**

(1) **Organic matter and nitrogen:**

In a previous section (Page 13) we noted that the organic matter in virgin soils was derived from the native vegetation, etc. In the case of forest soils the organic matter is deposited chiefly

as a leaf mat on the surface, but in the case of prairie soils, roots are added annually between the soil particles and the structural aggregates. The roots of different species of plants decompose at different rates. Some fibrous roots, like those of the native grasses, are tough and are attacked slowly by organisms, others, like those of the annual cereals, speedily disintegrate. Hence, the ability of the fibrous roots to bind the soil into aggregates after the death of the plant depends upon the ability of the roots to resist disintegration. Nevertheless, all fibrous roots break down sooner or later into organic mould (or finely disintegrated organic matter). This organic mould increases the friability, workability and permeability of clay soils, it improves the cohesion and water retention capacity of light textured soils, and it improves the physical condition of all soils.

Soil organic matter is also the source of energy for the soil organisms, it is a storage reserve for certain plant nutrients, but especially is it a source of nitrogen. Other things being equal, a soil that is well supplied with organic matter will produce plants with dark green leaves, whereas a soil in which the organic matter and nitrogen are very low will produce unthrifty plants with pale yellow-green leaves. Therefore the maintenance of organic matter in the soil at a reasonable level is essential.

Under virgin conditions, the good textured prairie soils developed a high level of organic matter and a dark color, under a fallow-grain system of culture the organic matter content falls to a lower level and the color of the soil becomes lighter because less organic matter is added to the soils in the crop residues, and because cultural conditions favor rapid decomposition. It should not be assumed however that the seeding down to grasses or clovers for one year will bring the organic level in the soil back to what it was under virgin conditions. Under no system of arable culture can the organic matter in the soil be kept as high as if it were under permanent grass and associated herbaceous vegetation. The high level of organic matter in the virgin soils is the cumulative effect of thousands of years of organic deposition. However, the important point is not, can the organic matter in the arable soils be restored to former levels (i.e., as in virgin soils), but can it be maintained at a satisfactory level?

In this connection it is of interest to recall that before the introduction of clover and turnips into England, a system of cropping that lasted from the time of the Romans to the 17th or 18th centuries was followed in certain districts. This system consisted of fallow, followed by winter wheat, which was succeeded by spring sown crops of barley or beans. The fallow however under this

medieval system was not the bare fallow with which we are familiar under dry farming conditions. Weeds and volunteer plants produced a growth of vegetation that was either grazed or mixed into the soil with crude implements. Moreover, the value of farm manure in the improvement of the soil and of crop yields was known from very early times and the manure from the farm yards was applied to the fields. This system of cropping lasted a long time, but the high yields common in later periods were not achieved until clover was introduced, and until lime was added to neutralize soil acidity, and bones were added to supply phosphate.

With the introduction of turnips and clover from the continent, however, the three-course field system of cropping was changed to a four-year rotation. The fallow was discarded and the grain crops were separated in the one case by red clover and in the other case by turnips. The introduction of clover and turnips gave more feed, hence more stock was kept, and more manure produced and applied to the land, with the consequence that the yields increased.

The long period of time in which a fallow-grain system was followed in England in medieval times, however, cannot be held as evidence that the present fallow-grain system which is followed in Manitoba will be satisfactory for hundreds of years. The reason for this is, first, that for fallow to be effective in moisture conservation, the growth of plants which will produce organic matter must be prevented during the moisture storage season; and second, that under a semi arid climate, organic matter is removed from the soil in clouds of black dust. Hence under Manitoba conditions the organic matter in a number of soils has been reduced, by wind erosion, much below the level at which it would be maintained by the residue from the grain crops.

Another important difference is that, under the extensive system of grain growing prevalent in Manitoba, the amount of manure produced is much too small to make any appreciable effect on the organic matter content of the soils. Roughly, about four tons of air dried feed and bedding will produce about seven and one-half tons of fresh farm manure. One ton of manure would be made up of about 500 pounds of dry organic matter and 1500 pounds of water. Hence, if 10 tons of manure were applied per acre, the organic matter which would be added by one application would be 500 x 10 = 5000 pounds. An acre of soil down to the depth of plowing ($6\frac{2}{3}$ inches) weighs approximately two million pounds. Therefore 5000 pounds of organic matter is only one-quarter of one per cent. of the weight of the plowed portion of the soil. When mixed with the soil, the organic matter of the manure decomposes and shrinks in volume. Even assuming that

the organic matter in the soil is increased by one-quarter of one per cent., by a ten-ton application of manure, this mount is less than the amount which could be removed by the wind in a dry windy season. Hence, the importance of controlling soil drifting is obvious.

Under a system of grain growing therefore it is obvious that some other method has to be followed in order to maintain the organic matter in the soils at a satisfactory level. The only method of maintaining organic matter in the soil at a satisfactory level under a grain growing system of agriculture is to reduce soil drifting, and to periodically retire the land back to perennial crops. For soil improvement, neither grass alone nor clover alone is satisfactory. Clovers are tap rooted rather than fibrous rooted, and when plowed under, the roots cannot bind the small soil aggregates into the large aggregates necessary to resist wind erosion. Moreover, the roots of the grass (which are desirable from a standpoint of binding the soil together) have a very low amount of nitrogen in proportion to the amount of carbon. Consequently the soil organisms which decompose the organic matter cannot get the amount of nitrogen they require from the grass residues, and hence they must compete with the growing plants for the soluble nitrogen of the soil. This may result in a temporary lowering of the yield and in the unsatisfactory results obtained when the grain is sown after a crop of timothy or other grass crop. From a soil improvement standpoint, therefore, mixtures of grasses and legumes are better than grass alone or clover alone. Mixtures of grasses and legumes are also better both for hay and for pasture than grass or clover sown separately. (Nature has had plenty of experience in the building up of soils, she never makes the mistake of planting pure stands, she always uses mixtures.)

The desirability of sowing grasses, legumes and mixtures for soil improvement purposes will be readily admitted. The practical difficulty lies in establishing satisfactory stands and in utilizing the perennial crops after they have been established.

With regard to the place grasses and clovers should occupy in the cropping scheme there are two alternatives. In districts in which moisture is not an acute problem, grasses and legumes may be worked into a system of cropping, in which the grasses and legumes are grown for two or more years in rotation with the other crops. The difficulty of obtaining a satisfactory stand of grasses or legumes prevents a rigid rotation system from being successfully followed in districts subject to drought and grasshopper injury. The alternative scheme which appears to be the most feasible is for a portion of the farm to be temporarily retired

to grass by seeding down the soil improvement crops only when moisture conditions are favorable. Such seeding may be left down for four or five or more years, while the remainder of the farm is cropped under the present fallow-grain system, but with provisions being made to control soil drifting by trash cover or other means. After a few years, when favorable moisture conditions again prevail, a second portion of the farm can be seeded down, thus permitting the first seeding to be broken up. This periodic method of seeding down to grass only when conditions are favorable and periodically bringing new land into cultivation (and combining grain growing with grazing), would appear to be the one most worthy of trial in the open plains. In a number of cases a combination of the two systems could be used, that is, where the farms are large and the number of livestock limited, the acreage near the buildings could be cropped under a systematic rotation of grasses and clovers alternated with grain and other crops, while the main portion of the farm was utilized under the more extensive grain growing and grazing system. The proportions of the areas devoted to grass and to grain under this scheme would vary with the soil requirements from a 20-80, to a 50-50 basis.

Such systems of land utilization could readily be established if markets were available for the stock which could be supported on the soil improvement crops. Hence the establishment of a permanent system of agriculture is linked up with the question of the extension of markets. Diversification of land-use would follow if diversification of markets could be obtained.

(2) The mineral nutrients:

The only method of maintaining a supply of mineral nutrients (phosphate and potash) is to add them in the form of fertilizers, as and when they are required. As a general rule the arable soils of Manitoba have a fairly high level of these elements, but here and there soils occur which show either a low phosphate content or a low availability of the phosphate. However, no matter how great the supply of mineral elements, the time will eventually come when steps must be taken to return to the soil the elements which have been removed.

How much nitrogen, phosphate and potash are removed from the soil in producing a bushel of wheat? An analysis made by the Soils Department of wheat produced on the University Farm, Winnipeg, shows that the following amounts of fertilizer ingredients were removed in a bushel of wheat and one hundred pounds of straw.

	Pounds of Nitrogen	Pounds of Phosphate	Pounds of Potash
1 bushel of wheat contained	1.59	.59	46
100 lbs. of straw contained	.85	16	2.49
Totals	2.44	.75	2.95

Assuming that 100 pounds of straw yield one bushel of wheat, a simple calculation shows that a 20-bushel crop of wheat removes 48.8 pound of nitrogen, 15 pounds of phosphate and 49 pounds of potash from the soil. Further, if we assume that the equivalent of forty 20-bushel crops have been produced on some farms in Manitoba since they were broken, it would follow that in a little over one-half a century (after allowing for fallow), an acre of land would have produced 800 bushels of wheat and 40 tons of straw. These quantities of produce would have removed from the soil approximately 1,952 pounds of nitrogen, 600 pounds of phosphate and 2,360 pounds of potash. To emphasize further the respect with which we should treat our fertile soils it may be pointed out that if the 600 pounds of phosphate and 2,360 pounds of potash had to be purchased as commercial fertilizer, it would require fourteen 100-pound bags of 43% Triple-superphosphate, and forty nine 100-pound bags of 48% Potassium sulphate to equal the amount removed in a half-century of cropping. To purchase this amount of fertilizer (exclusive of nitrogen removed), at present prices it would cost approximately $200.00.

How long can we go on taking these elements out of the soil? In respect to nitrogen, the solution is fairly simple. One ton of clover hay contains approximately 40 pounds of nitrogen, and one ton of alfalfa hay about 50 pounds of nitrogen. Hence, if the nitrogen in the soil becomes low, clover or alfalfa should be grown. A two ton crop of alfalfa will fix (2 x 50) 100 pounds of nitrogen. Clover and alfalfa (by the aid of bacteria) can obtain nitrogen from the soil air, and thus a satisfactory supply of nitrogen can be assured. Phosphate and potash, on the other hand, are of mineral origin and the plants can only add to the soil the minerals which they first remove from it.

How much phosphate and potash is contained in our soils, and when will the level of these two fertilizer ingredients be reduced to the point where satisfactory crops cannot be secured? At first thought it might appear to be a simple matter to analyze a soil to find out how much phosphate and potash is present, and then to calculate how long the supply would last. However this is not a practical approach. The total amount of these elements could be determined by analysis, but the figures obtained would be of little

value. The amount of fertilizer ingredients available to plants in any year cannot be determined beforehand. The difficulty is that soils are no good at arithmetic. If they are taken into the laboratory and asked (by analysis) how much plant nutrient is available, they will give one answer today, and another tomorrow, and next week they will give a crazy answer that is entirely different again. The reason for this is that only a relatively small portion of the total amount of plant nutrients present in the soil is available to plants. The amount of phosphate and of nitrogen that is available depends upon the climate (or weather). Therefore, it is to be expected that the amount of available nutrients will fluctuate from time to time as the season changes or as the weather fluctuates. There is no sure method of determining the amount of nutrients available except to plant a crop with and without fertilizer and note the results. If the level of available nutrients is too small for normal growth, the fact will be indicated by certain mal-nutrition symptoms in the crop and by reduced yields. If these disappear with the application of fertilizer, the procedure indicated is obvious. The wise operator who has not been following the practice of applying fertilizer should periodically plant a trial strip on one or more of his fields and then note the results, for not only should he be prepared to forestall a deficiency due to low soil fertility, but he should be prepared to cope with a temporary deficiency due to unfavorable climate.

In conclusion the essential points raised in this study-section may be sumarized as follows

(1) Continued arable culture should not be attempted on light textured or on submarginal soils.

(2) The good arable soils should be preserved and kept permanently productive.

The problem of maintaining the productivity of the arable soils in Manitoba involves:

(a) The combating of drought.

(b) The control of soil erosion by wind and by water.

(c) The maintenance of the organic matter of the soil at a satisfactory level, and

(d) When the level of mineral nutrients falls to unproductive levels, to apply same in the form of commercial fertilizers.

The establishment of a permanent system of agriculture in Manitoba is the concern not only of the land operator, but also of municipal and provincial governments. The Federal govern-

ment, through the Prairie Farm Rehabilitation Act, are co-operating with the provincial and municipal governments, as well as with individual farmers, with the object of developing agriculture in the prairie region on a more permanent basis. The activities under the Federal Prairie Farm Rehabilitation Act are briefly summarized in twelve pamphlets which can be obtained from the Prairie Farm Rehabilitation office in Regina. They are described in more detail in the quarterly issue of the C.S.T.A. Review for December 1939, under the title of "Prairie Farm Rehabilitation."

Each municipal official should also be acquainted with the provincial Land Rehabilitation Act, which was put on the Statutes in April 1939, to enable the municipalities and groups of land owners to collectively undertake improvements in land utilization.

The challenge is ours. Let us to the task.

"The Lord God
Gave to Man the Land,
Not only to subdue
But also to replenish,
His, the long-enduring task
Plenty to provide
And lasting Peace establish.
His, alone, the toil;
His, the power to know
The land, the seed,
The wind, the driving rain,
And while supplying every need,
Preserve the sacred soil
For all Mankind.

To leave the land
A better land
For those who tread the fields
He oft has trod
Makes Man part-maker
Of his destiny,
Makes him a laborer
*Together with his God"**

*J. Gladden Hutton, Brookings, S.D., 1936.

Questions:

1. What are some of the signs of soil deterioration, and can any of them be observed in your locality?

2. What are some of the methods of combating drought that should be followed under the conditions which prevail in your district?

3. What can be done to prevent or to control soil drifting; should the extensive planting of field shelter belts be undertaken as a community enterprise?

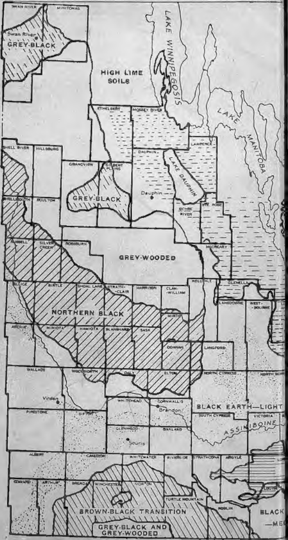
4. Do the soils of your district show any signs of injury by water erosion, and if so, what should be done about it?

5. Is provision being made to supply the soils periodically with organic matter?

6. What kind of fertilizer, if any, do the soils of your district require?

REFERENCE BOOKS ON SOILS AND NATURAL RESOURCES

	Title	Author	Publisher
1.	The Soils of Manitoba.	J. H. Ellis	King's Printer, Parliament Bldg., Winnipeg, Man.
2.	Reconnaissance Soil Survey of Southwestern Manitoba.	J. H. Ellis & Wm. H. Shafer	King's Printer, Parliament Bldg., Winnipeg, Man.
3.	The Rape of the Earth.	G. V. Jacks & R. O. Whyte.	Faber & Faber, London.
4.	The Land Now and Tomorrow	R. D. Stapledon	Faber & Faber, London.
5.	Rich Land, Poor Land	S. Chase	McGraw-Hill Book Co. Inc. New York and London.
6.	Soils and Men.	U.S. Dept. of Agriculture Year Book, 1938	
7.	Soil Conservation.	H. H. Bennett	McGraw-Hill Book Co. Inc. New York and London.
8.	Soil Erosion and Its Control.	Q. C. Ayres	McGraw-Hill Book Co. Inc. New York and London.
9.	Soil Science.	W. W. Weir	J. B. Lippicot Co., Chicago & Philadelphia.
10.	Soils and Soil Management.	A. F. Gustafson	McGraw-Hill Book Co. Inc. New York and London.
11.	Land Drainage and Reclamation.	Q. C. Ayres & D. Scoates	McGraw-Hill Book Co. Inc. New York and London.
12.	Range and Pasture Management.	A. W. Sampson	John Wiley & Sons, Inc., New York and London.
13.	Provincial Crop Bulletins (Annual)		Publications Branch, Parliament Bldgs., Wpg.
14.	Proceedings of the Conference on Markets for Western Farm Products.		King's Printer, Parliament Bldg., Winnipeg, Man.
15.	Mineral Resources of Manitoba	G. E. Cole	King's Printer, Parliament Bldg., Winnipeg, Man.
16.	Water Resources of Manitoba.	C. H. Attwood	King's Printer, Parliament Bldg., Winnipeg, Man.
17.	Forests of Manitoba.	H. I. Stevenson	King's Printer, Parliament Bldg., Winnipeg, Man.
18.	The Climate of Manitoba.	A. J. Connor	King's Printer, Parliament Bldg., Winnipeg, Man.
19.	Commercial Fishing Industry of Manitoba	H. C. Grant	King's Printer, Parliament Bldg., Winnipeg, Man.
20.	The Fur Industry of Manitoba.	M. E. Melven	King's Printer, Parliament Bldg., Winnipeg, Man.
21.	Surface Deposits and Ground Water Supply of the Winnipeg Map Area.	W. A. Johnston	Memoir 174, Canada Dept. of Mines, Ottawa.
22.	The Last Million Years.	A. P. Coleman	University of Toronto Press.
23.	Agricultural Machinery	J. B. Davidson	John Wiley & Sons, Inc., New York and London.
24.	Prairie Farm Rehabilitation Circulars, 1-12		Prairie Farm Rehabilitation Office, Regina, Sask.
25.	Prairie Farm Rehabilitation.		C.S.T.A. Review, Dec. 1939, Ottawa.
26.	Manitoba Land Rehabilitation Act.		King's Printer, Parliament Bldg., Winnipeg, Man.


SWAN RIVER
MINITONAS
Swan River
GREY-BLACK
HIGH LIME
SOILS
LAKE WINNIPEGOSIS
LAKE MANITOBA
ETHELBERT
DAUPHIN
LAKE DAUPHIN
LAWRENCE
SHELL RIVER
HILLSBURG
GRANDVIEW
GILBERT PLAINS
GREY-BLACK
Dauphin
BOULTON
RUSSELL
SILVER CREEK
ROSSBURN
GREY-WOODED
MCCREARY
ROSEDALE
GLENELLA
ELLICE
BIRTLE
SHOAL LAKE
STRATH-CLAIR
HARRISON
CLAN-WILLIAM
NORTHERN BLACK
LANSDOWNE
WEST-BOURNE
ARCHIE
MINIOTA
HAMIOTA
BLANSHARD
SASK
ODANAH
LANGFORD
WALLACE
WOODWORTH
DALY
ELTON
NORTH CYPRESS
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WHITEHEAD
CORNWALLIS
Brandon
BLACK EARTH—LIGHT
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OAKLAND
Souris
ALBERT
CAMERON
WHITEWATER
RIVERSIDE
STRATHCONA
ARGYLE
EDWARD
ARTHUR
BRENDA
WINCHESTER
MORTON
TURTLE MOUNTAIN
ROBLIN
BROWN-BLACK TRANSITION
BLACK
GREY-BLACK AND
GREY-WOODED